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14. ABSTRACT

During year three of the Anthro-Centric Multisensory Interface Vision Augmentation/Substitution (ACMI-VAS) project, the research team refined the integrated sensory substitution system for vision loss that mimics the function of the retina developed in year one. The ACMI-VAS concept uses a video camera connection to, or data from, a computer to represent, tactually, high-resolution narrow field, mid-resolution wider field and low-resolution 360 degree visual information simultaneously.
We have integrated a method to enable identify colors tactually. We received approval for an experimental protocol to evaluate the testbed hardware and software against a single tactile display for human research participants (military and civilian) who have profound blindness. Tasks in the protocol include reading, visual acuity, web browser navigation, walking an obstacle course and identifying colors. The protocol will be completed in the next reporting period.

15. SUBJECT TERMS
Blindness, human machine interface, sensory substitution, tactile interfaces

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Table of Contents

Introduction

Servicemembers who suffer combat, training, or accidental injuries that damage their sensory capabilities can have great difficulty returning to productive lifestyles once healed from their initial trauma. Sudden loss of vision can overwhelm a previously healthy individual's ability to interact with the world, adversely impact the individual's recovery from physical and emotional trauma, and prevent a return to the community as a productive, stable member of society. This project seeks to advance technologies for non-invasive vision sensory substitution and augmentation in order to allow these individuals to return to more normal, healthy social interactions. This project exploits two specific capabilities of the human central nervous system, namely cross-modal sensory interactions and brain plasticity, to address the needs of these injured servicemembers. Perception takes place in the brain, not at the end organ (Bach-y-Rita, 1972); therefore, the brain can learn to reinterpret the meaning of signals from specific nerves (e.g., from tactile receptors) given appropriate self-generated feedback. This forms the basis for interfaces that can non-invasively and unobtrusively use alternative sensory pathways to provide information. The Florida Institute for Human and Machine Cognition (IHMC) will develop a proof of concept prototype Anthro-Centric Multisensory Interface for Vision Augmentation/Substitution (ACMI-VAS) system. We envision that with appropriate development, the ACMI-VAS concept could be integrated and reduced in size to provide a robust situation awareness (SA) of visual information during activities of daily living (ADLs).

Body

Traumatic brain injury (TBI) can also induce loss of one or more sensory capabilities. Intermittent or permanent loss of veridical sensory information adversely affects SA, leading to an inability to perceive and comprehend the meaning of elements in the environment and to project their future states. Without accurate SA, one's ability to interact in a dynamically changing world diminishes (Endsley, 2000). The sequelae of TBI and somatic polytrauma suffered by this growing population may evolve over many months after injury, manifesting as significant loss of one or more sensory channels well after a traumatic event (Owens, 2008). While current technologies for noninvasive sensory substitution provide an inadequate replacement for lost sensory capabilities, they can augment residual sensation. In addition, when integrated with other substitution technologies, these technologies can improve SA, and therefore open opportunities to injured servicemembers that they might not otherwise investigate. This research and development project seeks to leverage a number of current technologies as well as some that are under development into a novel multi-sensory vision augmentation/substitution interface that will enable wounded servicemembers to regain some measure of normal visual interactions and functional return to ADLs.

Sensory loss can be addressed by using precisely positioned large magnetic fields (Kupers et al., 2006) or surgically with implanted devices like cortical (Dobelle, 2000; Fernández et al., 2005) direct nerve implants (Chai, et al. 2008) and end organ stimulators, such as cochlear or retinal implants (Zhou & Greenberg, 2005; Weiland, Liu, & Humayun 2005; Veraart et al., 2003; Maynard, Nordhausen, & Normann, 1997; Rauschecker & Shannon, 2002), but this adds both surgical trauma and risk of infection (Reefhuis et al, 2003). A recent Australian government initiative provided funding for the development of both supra-choroidal and direct cortical (V1) stimulation arrays. The initiative's supra-choroidal development plan includes an initial low density 98 element array followed by an eventual high density 1000 element array (Ong and da Cruz, 2011). These devices require chronic indwelling implants (Figure 1) that, at the current state of the art, provide limited resolution (e.g., to 20/120 equivalent vision, Dobelle, 2000: Ahuja, et al; 2011) and, in the case of cortical implants, may induce seizures (Javaheri et al., 2006; Kotler, 2002). While technological advances have and will continue to dramatically increase resolution available from retinal implants (Zrenner et al., 2010; Stingl, et al, 2013), they still require invasive surgery, indwelling foreign bodies and an intact oculus. Given the rapid development of modern electronics, wireless communications, batteries, and computer technologies, it stands to reason that implanted devices will also continue to improve qualitatively rapidly and patients who receive implants will need to seriously consider the risks and benefits of “upgrading” their prostheses through more surgery. Servicemembers blinded from battlefield polytrauma will have likely endured multiple surgical procedures by the time they have stabilized sufficiently to consider a retinal or cortical implant and may not be candidates due to injury to underlying neural tissue (retina), pathways (optic nerve), or cortical processing (occipital lobe). An alternative solution to this form of sensory replacement, namely sensory substitution, has shown promise for blind individuals and can tolerate damage in any of these components that make up the “retinex” (Land, 1964) normally required for human perception of the visual environment.

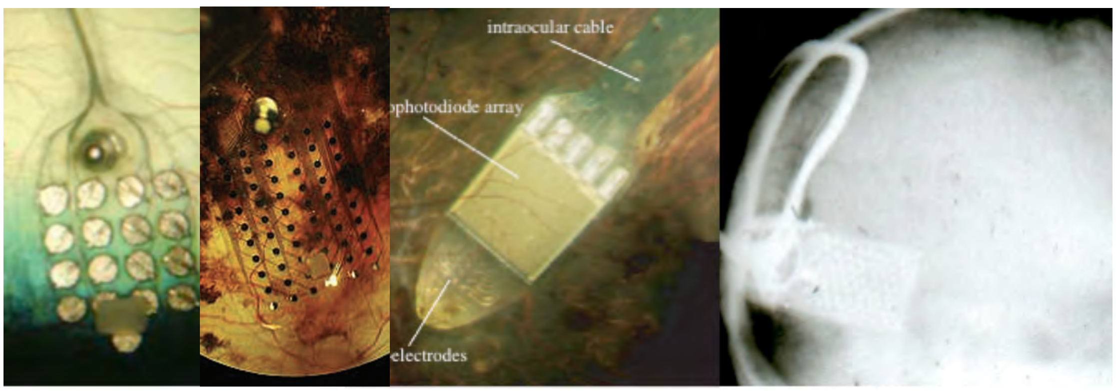

Figure 1: (*left)* Photograph of the Argus™ I and II Retinal Prosthesis System epiretinal microelectrode arrays (Second Sight Medical Products, Inc, Sylmar, CA) recently approved for use in the United States (*note increase in electrode density from 16 to 60 electrodes between Argus I and Argus II*). (*center*) Retinal Implant AG (Reutlingen, Germany) subretinal combined photodiode/electrode array with 1500 sensors and electrodes. (*right)*, X-ray of implanted cortical array (Dobelle, 2000) positioned on the occipital cortex.

Perception takes place in the brain, not at the end organ (Bach-y-Rita, 1972); therefore, the brain can learn to reinterpret the meaning of signals from specific nerves (e.g., from tactile receptors) given appropriate self-generated feedback. This forms the basis for interfaces that can non-invasively and unobtrusively use alternative sensory pathways to provide information. This means that the information displayed does not necessarily need to represent the underlying data at high resolution, rather abstract representations of the sensory environment information can provide sufficient data for operator decision making and improved SA (Raj, Kass, & Perry, 2000). Such sensory substitution mechanisms exploit the plasticity inherent to the brain and nervous system, supporting both long term and short term anatomical and functional remapping of sensory data (Finkel, 1990; Walcott & Langdon, 2001). Sensory substitution refers to the remapping of sensory data from the normal sensory receptor field for a particular type of data to other channels of information perception (Bach-y-Rita, Collins, Saunders, White, & Scadden, 1969). With appropriate feedback, the plasticity of the human brain allows individuals to learn to perceive the substituted data with little cognitive effort, especially if training is provided soon after sensory loss (Bavelier & Neville, 2002). For maximal benefit, the interface must also intelligently pre-process the incoming data to account for differences in capability between the alternative channels and the ones normally used to perceive given sensory data, as well as provide intuitive control and data management. Many sensory substitution devices and approaches have been developed over the past decades (Machts, 1920). Modern computer and electronic design, however, now enables the development of intelligent, noninvasive interfaces unobtrusive enough for use in everyday activities.

Neural projections from the visual, auditory and proprioceptive sensory systems interact in the brainstem at the superior colliculus (Meredith & Stein, 1986; Wallace & Stein, 2000) and higher levels (Fort et al., 2002), where mechanisms such as non-synaptic diffusion neurotransmission (as well as synaptic connections) can cross-modally engage different sensory channels (Bach-y-Rita, 1995). In addition, crossmodal activity has been demonstrated in the primary and secondary cortical processing areas for individuals with and without sensory impairment (Schroeder & Foxe, 2005). For example, deaf individuals show activation in the auditory cortex in response to visual stimuli (Finney, Fine, & Dobkins, 2001), blind individuals show visual cortex activity in response to touch (Sadato et al., 1996; Sadato et al., 2004; Sathian, 2005) and vibratory stimuli (Burton, Sinclair, & McLaren, 2004), and auditory stimuli can elicit changes in somatosensory cortex activity (Foxe et al., 2000). The fact that these interactions exist and become more pronounced given sensory channel deprivation (Sathian, 2005) supports the use of sensory substitution as a potential solution for partial restoration of lost sensory channels.

With veridical multisensory information, these mechanisms appear to enhance perception accuracy and reaction time (Deiderich, 1995) as well as modulate ongoing cognitive processes (Schroeder & Foxe, 2005) while improving workload performance and SA (Wickens & Holland, 1999). By exploiting this cortical crossmodal integration (Calvert, 2001), we and other researchers have shown that individuals with sensory loss due to artificial restrictions, disease, congenital defect, or injury can use sensory substitution interfaces to exploit this inherent plasticity of the brain and nervous system for both long term and short term anatomical and functional remapping of sensory data (Walcott & Langdon, 2001; Ptito, Moesgaard, Gjedde, & Kupers, 2005; Kaczmarek, Bach-y-Rita, Tompkins, & Webster, 1985) and improvement in SA (Raj, Kass, & Perry, 2000; Saunders, Hill, & Franklin, 1981). Recent brain imaging studies have confirmed crossmodal modulation of activity across different sensory cortices that vary depending on whether multiple sensory channels provide congruent information or incongruent information (Johnson & Zatorre, 2005; Jones & Callan, 2003; Fort et al., 2002; Laurienti et al., 2002). Because attentional resources or cognitive effort required to process the sensory channel data also manifests as intersensory cortical activity modulation (Loose et al., 2003; Kanwisher & Wojciulik, 2000; van Wassenhove, Grant, & Poeppel, 2005; Mozolic et al, 2008), multisensory aids for the blind must minimize sensory display complexity to reduce cognitive demands.

A number of options for visual sensory substitution exist, however, the two most investigated methods use audio and tactile representations, respectively, of visual information. The Braille tactile alphabet represents the most common example of tactile substitution using two columns of six or eight raised bumps either embossed on paper or presented using a mechanical device. While this has worked well for plain text transcriptions, it becomes unwieldy for graphical information for technical information such as mathematical formulas (Moço & Archambault, 2003) and the graphically rich visuals of magazines, the Internet and the natural world. (Boehm, 1986; Ifukube, Sasaki & Peng, 1991). An alternative technique promoted by Meijer (1992) called “The vOICe“ system converts images into an audio time multiplexed frequency and amplitude representation that sweeps across successive frames of video to encode spatial information into a complex audio stream (Amedi et al., 2005). The biggest drawback to these systems related to the amount of training required to become fluent in the alternative representation and the fact that these methods heavily engage the remaining senses. With Braille, the reader’s hands are unable to perform other ADLs (such as making a sandwich). The vOICe system audio display and computerized text to speech screen readers such as Job Access With Speech (JAWS®, Freedom Scientific, Inc., St. Petersberg, FL) (Bryant & Bryant, 2003) as well as more recent multimodal computer interfaces for the blind (Yu et al., 2006) require significant auditory cognitive engagement and may prevent accurate sensing of events in the ambient acoustical environment (e.g., a ringing telephone). Portable camera based readers such as the knfbReader Mobile (K-NFB Reading Technology, Inc., Newton Lower Falls, MA) allow the blind to carry optical character recognition into the real world, but camera resolution and lack of context of the visual environment (Gaudissart et al., 2005) make such systems cumbersome to use in practice (e.g., the user does not have a sense of the size of the type or if there is any text to recognize without additional input from a sighted individual).

The Florida Institute for Human and Machine Cognition (IHMC) has, therefore, focused on integration and development of non-invasive methods of presenting visual information to blinded servicemembers using sensory substitution. By leveraging previous work for the United States Navy and the National Aeronautics and Space Administration (NASA) originally designed to enhance SA for aviators and astronauts, along with modern tactile technologies designed for the blind, we have developed prototype hardware components that could provide a substantial level of visual sensory information. With early versions of these components, we have provided partial demonstrations to and solicited early feedback from four recently blinded military servicemembers. These evaluators suffered polytraumatic injuries that resulted in enucleation of both eyes 10-48 months prior to participation. All had and at least one ocular prosthetic fitted. Two existing tactile interfaces were demonstrated, the U. S. Navy/NASA/IHMC Tactile Situation Awareness System (TSAS) and the video camera based Wicab, Inc., (Middleton, WI) BrainPort® Wearable Aid for Vision Enhancement (BP-Wave II). The former provided a limited sense of peripheral visual object detection using 24 electromechanical vibro-tactile transducers (tactors) mounted in a garment that creates a three-dimensional tactile torso interface (TTI) array on the body. The latter consisted of an 18x18 array of electrotactile tactile transducers placed on the user's tongue in a two dimensional array, now available as a 20x20 array for clinical research or as a 25x25 prototype (Figure 2).

Figure 2: Blind servicemembers using prototype sensory substitution interfaces. (*left*) Using the TTI to receive peripheral attention directing tactile cues. (*center left*) Using the BP-WAVE II to negotiate stairs without assistance and (*center right*) to read text. (right) BrainPort® Intraoral Device (IOD) electrotactile tongue array (~600 active tactile pixels).

With these systems we have demonstrated awareness of nearby objects on the torso and, through the BrainPort® tongue array, identification of shapes, shape orientations, reading (up to 4-5 word sentences), catching balls rolled across a table, navigating unfamiliar office spaces, negotiating stairs, identifying open parking stalls from ones with vehicles, performing standard visual acuity tests to 20/40 equivalent using standard eye charts and recognizing family members (Figure 3). Each individual trained to perform these tasks in less than 4-6 hours.

Figure 3: Initial BP-WAVE II activities performed during technology demonstrations with recently blinded servicemembers. *left to right, top to bottom*, Catching balls, navigating office spaces, locating open parking stalls, noticing infant's hair, and reading eye charts to 20/80 (*images used with permission*).

In addition, IHMC has demonstrated that a direct connection between the tactile interface and a computer graphical display can provide a superior qualitative experience by bypassing the limitations of cameras (e.g., glare, changing lighting conditions, focus and unintentional movements of the head). While this direct connection removes the need to position the user in front of a computer (a useful capability for those with orthopedic or other injuries that prevent prolonged upright posture), we have prototyped two methods of tactile computer interactions that mimic sighted interactions. Using video oculography, we have demonstrated that blind individuals can use extraocular musculature to control insensate eyes (even prosthetic ones) with sufficient accuracy to pan and scan to read across an image presented tactually. Likewise, head position can control image zoom such that a blind user can lean toward or away from an object of interest to zoom in or out. In the current implementation, looking away from the computer screen automatically switches to direct camera feed, which allows the user to look down at the keyboard when typing or observe other items in the environment. Alternatively, we have also implemented a touch screen mechanism that allows the user to feel the pixels under his or her fingertip via the tongue while dragging across the screen (Figure 4). Both mechanisms have been mastered by participants in less than 30 minutes, indicating that the method does not significantly task cognitive resources.

Figure 4: Direct computer tactile (BrainPort®) interface demonstrations. *left*, participant prepares to use eye/head tracking apparatus to determine point of gaze despite the users' prosthetic eyes. The software determines if the participant is looking at the screen and returns a 100-200 pixel sample of the screen image. The user intuitively controls zoom level by leaning either toward or away from the screen. Looking down automatically selects a gaze directed subsample of the video image from the head mounted camera (allowing the user to find keys on the keyboard). r*ight*, When the user touches the screen, the subsection of the screen image underneath the fingertip is presented to the tongue instead.

Two major issues were noted with the prototype system evaluations, namely registration of gaze position relative to the visual task and perception of changes in the environment outside the field of view of the camera. When reading, for example, inadvertent head and body movements caused the camera image to move away from the word or letter of interest. Reacquisition of the word or letter required additional panning and scanning in order to find the line of text and the word or letter. The lack of peripheral visual sensation appeared to cause a high level of anxiety for recently blinded individuals (who may not have yet adapted to their visual loss). Blind individuals are often startled when others approach quietly and begin talking to or make physical contact with them. These effects would still occur even if the IOD received data from prosthetic eyes with embedded cameras (figure 5), due to the lack of visual context and peripheral vision.

Figure 5: Electronics (left) embedded in the camera-enabled prosthetic eye (right) developed by the Eyeborg Project (Toronto, Canada). Downloaded from http://eyeborgproject.com.

These issues warranted the integration of additional displays and sensors to provide paracentral and peripheral visual information and a sense of gaze location within the broader visual context. Following the initial technology demonstrations, IHMC aggregated these prototypes in order to improve a user's tactile visual sensory substitution perception. Using the BP-WAVE-II prototype and the previous generation VideoTact, we determined that tasks that required serial visual scan, such as reading, visual acuity testing, identifying shapes arrange in rows and columns, etc., could be performed more easily when using the two tactile interfaces simultaneously (Figure 5).

Figure 5: Initial mock up of ACMI-VAS for foveal and paracentral vision substitution. Image (upper right inset) presented on the VideoTact (upper left inset) is zoomed in less than the BrainPort® image zoom level (center display of lower right inset) to provide a slightly wider field of view. The physical size of the components has been reduced significantly and control of the combined technologies has also been simplified using IHMC's AMI architecture.

IHMC used its existing, in-house developed Adaptive Multiagent Integration (AMI) software architecture, which can easily connect components such as displays, sensors, algorithms and adaptive automation via a standardized Java (Sun Microsystems, Inc, Santa

Clara, CA) interface. AMI associates explicit ontological definitions with each agent that allow rapid integration of new components (as software agents) into the architecture because the system identifies and makes data connections between agents automatically, based on data types and relative quality of similar data streams. The large complement of devices, including video, motion capture, tactile and audio interfaces, pressure, orientation and psychophysiologic sensors, previously integrated as software agents (Johnson et al., 2005) were leveraged and additional agents were created as needed. The architecture is inherently scalable, using available processing power and allows unlimited nodes and agents on wired or wireless networks. Communications between agents are made peer to peer and support high data rates and both secure and open transport mechanisms. Sensor signals or processed data can be delivered to multiple displays across different modalities (e.g., video, audio, vibrotactile, electrotactile, etc.) simultaneously or separately, enabling side-by-side real-time evaluation of various sensory substitution implementations (Raj et al., 2005). Leveraging AMI for this project enabled rapid development of the ACMI-VAS prototype by taking advantage of existing software agents for a number of tactile interfaces (including torso, abdominal and tongue placed displays), various video cameras, peripheral range and bearing sensing, as well as head and eye tracking (e.g., OptiTrack, NaturalPoint, Inc., Corvallis, OR; RK-826y-BPCI, IScan, Inc., Burlington, MA).

Earlier in this project we developed a color filter assembly that mounts to an unmodified BrainPort® V-100 vision device that has a 400 pixel intraoral device (IOD) or to an earlier BrainPort® BP-WAVE-II with a 600 pixel IOD. We integrated a Playstation3 controller into a button pad interface box to reduce the number of items the user will have to manipulate.Three blind individuals evaluated this system and could identify primary, secondary and tertiary colors within 15-20 minutes (Figure 6).

Figure 6: Research staff (using BrainPort®) changing filter (black disk mounted to glasses) with Playstation3 game controller buttons to identify color of illuminated button pad.

By leveraging other funding vehicles following the initial technology demonstrations noted above, the ACMI-VAS system benefits from advances in the BrainPort®, the VideoTact and TTI (Figure 7). Notably, IHMC has acquired two BrainPort® V100 (20x20 pixel) units to replace the prototype BP-WAVE-II units. We have collaborated with ForeThought Development, LLC, to design a more compact VideoTact system that utilizes modern electronics components.

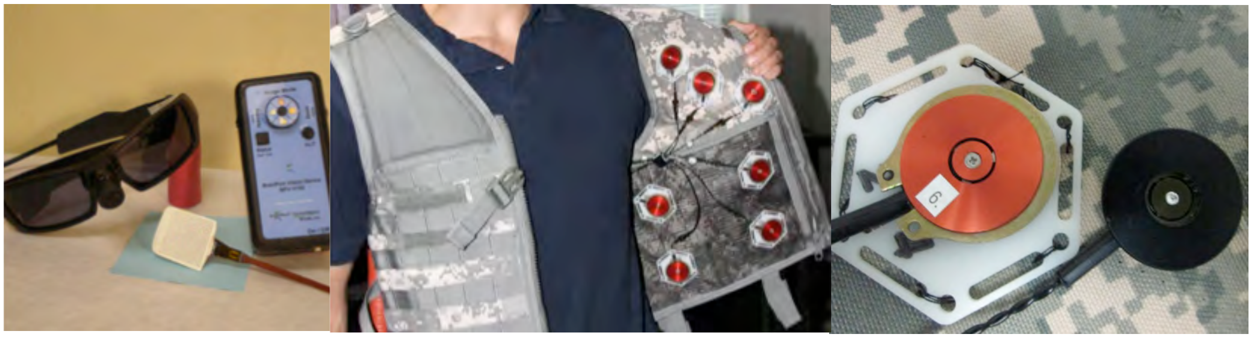

Figure 7: (*left*) Current BrainPort® V100 system showing sunglasses mounted camera, handheld embedded processor/user input device and 400 tactor IOD. (*center*) TTI with ACU mounted C-2 tactors and (*right*) comparison of C-2 (red) and C-3 (black) tactor sizes.

Lastly, we have developed a reflected infrared sensor range and direction detection system that can detect objects in the environment and represent their locations and motion using the TTI (Figure 8), which can use the much smaller, lighter weight C-3 tactors versus the larger, older C-2 tactors (Engineering Acoustics, Inc., Casselberry, FL).

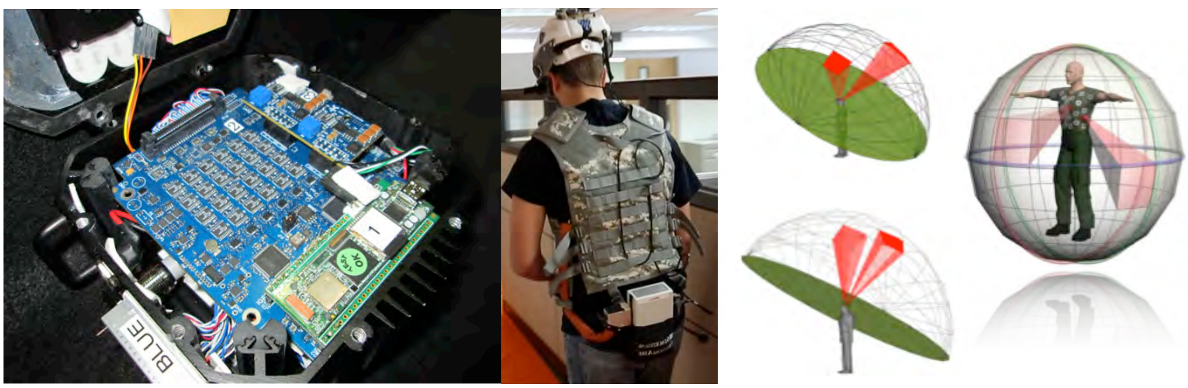

Figure 8: (*left*) IHMC's revised embedded microprocessor controlled 24 channel reflected infrared emission range and direction peripheral vision sensor PC-104 size circuit board with tactor drive capability. (*center left*) Schematic of head worn cap with embedded IR emitters and receivers detecting (*center right*) objects in the environment. (*left*) A second circuit board receives the signal and represents the information on the torso using the TTI.

These technology advances formed the basis of the ACMI-VAS central/paracentral and peripheral vision substitution concept. Because the V100 is now available as an investigational device for research applications, IHMC designed a study to compare blind performance on ADLs with the BrainPort® alone, or with ACMI-VAS (which includes the BrainPort® for foveal substitution, the VideoTact for parafoveal substitution, and the TTI for peripheral substitution).

In the ninth project quarter, the project received a no cost extension through 3QTR FY13. The research staff continued practicing the test protocol, which had been approved by the U. S. Army Human research Protections Office (HRPO) in the final month of the prior funding year. Under another funding vehicle, we also completed the design and fabrication of the initial miniaturized, battery powered TTI driver.

During this tenth reporting period, effort continued on hardware integration for the multisensory "haptic retina" system based on feedback from research staff practicing the protocol utilizing the new, smaller TTI driver system with the lighter weight C-3 tactors. The garment with these lighter tactors has been deemed more comfortable that the older C-2 Based vest by the research staff. Similarly, Forethought Development, LLC, continued fabrication of the ETv6 miniaturized VideoTact, however, component availability became a greater issue as the higher voltage parts necessary for electrodermal stimulation were discontinued as commercial electronics demand changed to lower voltage components. This modern unit will be much lighter and easier for participants to use. During this period we also increased the color gamut available on the color identification task. This results in a visible flicker of the LEDs that is not perceptible on the tongue. This allows us to more accurately generate specific colors.

In the eleventh reporting period, Forethought Development, LLC, completed the fabrication of the ETv6 miniaturized VideoTact array and driver circuit design and has begun work on the hardware controller for the miniaturized array. During this reporting period, the PI travelled to the Military Vision Symposium in Boston, MA, in September 2012. At this forum, the PI presented the current state of the ACMI-VAS project and the approach to be used in the human research participant testing.

Relationship to award Statement of Work

At the end of the third year of the program, we have developed a multisensory interface that provides visual substitution via tactile displays that provides a partial functional restoration of visual perception. Based on the original statement of work, we have completed the following tasks:

Specific Aim # 1: Develop a multi-sensory tactile interface to augment or substitute for recently acquired visual impairment

Task 1. Integrate IHMC Tactile interfaces for haptic retina application

- 1a. Finalize sensor integration plan for peripheral and central vision functions
- 1b. Develop integrated abdomen, torso and tongue display mounting system
- 1c. Develop multiple sensor hardware mounting system
- 1d. Develop software functional requirements
  - *Milestone #1: ACMI-VAS critical design review*

Task 2. Integrate visual sensory augmentation/substitution

- 2a. Evaluate feasibility of providing stereoscopic vision with current interfaces
- 2b. Define paracentral display icon for registration of foveation point
- 2c. Fabricate *REVISED* hardware for IHMC peripheral vision sensor

Specific Aim #2: Evaluate ACMI-VAS

Task 3. Code software for visual environment interactions

- 3a. Integrate central (foveal), paracentral and peripheral vision manual controls
- 3b. Develop calibration procedures for ACMI-VAS
- 3c. Code user interface
- 3d. Code performance evaluation interface
- 3e. Test and evaluate interface function with tactile and audio displays
- 3f. Define performance metrics and code software for evaluation of metrics
- 3g. Verify evaluation software functionality
  - *Milestone #3: ACMI-VAS haptic retina evaluation system design complete*

Task 4. Demonstration and evaluation

- 4a. Submit IRB and HRPO applications for use of human research participants
- 4b. Prototype system functional verification and testing

Remaining Tasks/Milestones:

Task 2. Integrate visual sensory augmentation/substitution

- 2d. Complete Integration of software (using AMI) of IHMC peripheral vision sensor
- 2e. Test & evaluate final ACMI-VAS haptic retina software/hardware integration

Milestone #2: Complete ACMI-VAS haptic retina prototype system

Task 4. Demonstration and evaluation

4c. Identify and recruit 20 recently blinded research participants
4d. Human participant testing
4e. Human participant data analysis
Milestone #4: Collect and analyze ACMI-VAS human research participant data
Milestone #5: Draft manuscript for submission to Ophthalmology (journal)

Deliverables: 1) HRPO application renewal, 2) Quarterly reports, and 3) Annual Report

Key research accomplishments (project years 1 through 3)

- We successfully integrated a prototype haptic retina via the AMI software architecture.
- We determined that serial visual tasks such as reading and identifying shapes on a grid was enhanced when using ACMI-VAS.
- We determined that colors could be identified tactually.
- We developed a test protocol to evaluate the effectiveness of the ACMI-VAS concept against the BrainPort® V100 alone.
- We received HRPO approval to begin human research participant testing.
- We fabricated a miniaturized TTI driver system

Reportable outcomes

Received HRPO approval for use of human research participants.

Conclusion

During years one through three of the ACMI-VAS project, we developed a prototype ACMI-VAS system and the research environment needed to evaluate it. We improved the user control interfaces and developed a method to allow tactual understanding of color. The final portion of this grant will focus on human research participant testing and evaluation, data analysis, drafting a publication detailing the results, and development of the final ACMI-VAS prototype design specification document. The noninvasive nature of the ACMI approach ensures that injured servicemembers could benefit from future upgrades as technologies improve (in out-years) without risks of further surgeries or infection associated with implantable devices. The proposed complementary interface displays can be tailored to suit the needs of an individual. For example, an injury that spared the peripheral vision may only require the higher resolution displays, whereas a condition like hemianopsia might only require a low-resolution spatial awareness component. This proposed technology development will result in a single integrated system prototype capable of providing an alternative mechanism for visual sensing of high resolution foveal vision, low resolution peripheral vision and stabilization of the imagery despite perturbations of the head. Even profoundly blind individuals would benefit from the modularity of the system as they could choose to use specific displays for any given activity. The use of the AMI software agent framework ensures that integration of improvements in any of the major technologies, including sensing devices (e.g., cameras) and interfaces (potentially even implantable ones) will occur quickly, speeding up evaluation of incremental changes and their deployment to the users.

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Appendix: Acronyms

- ACMI-VAS – Anthro-Centric Multisensory Interface for Vision Augmentation/Substitution
- ADL- Activities of Daily Living
- AMI – Adaptive Multiagent Integration
- BP-WAVE II– BrainPort® Wearable Aid for Vision Enhancement, version II
- FrACT – Freiburg Visual Acuity and Contrast Test
- HRPO – Human Research Protection Office
- IHMC – Florida Institute for Human and Machine Cognition
- IOD – Intra Oral Device
- IRB – Institutional Review Board
- JAWS – Job Access With Speech
- NASA – National Aeronautics and Space Administration
- RGB – Red, Green, Blue
- SA – Situation Awareness
- TBI – Traumatic Brain Injury
- TSAS – Tactile Situation Awareness System
- TTI – Tactile Torso Interface